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An Overview of Solid Waste Generation in the United States

Donna M. Lacombe

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AN OVERVIEW OF SOLID WASTE GENERATION IN THE UNITED STATES

by

Donna M. Lacombe

ABSTRACT

Over 5 billion metric tons of solid waste was generated in the United States in 1977. Quantities, composition, and disposal techniques are discussed for the major waste categories—agricultural, mining and milling, industrial, municipal, energy production, and radioactive waste. Continued research and development of adequate disposal methods and resource recovery and recycling processes is needed.

I. INTRODUCTION

Solid waste management, as it is practiced in the United States today, has progressed over the past 15 yr. Before 1965 open dumping, open burning, and ocean dumping were the primary methods of waste disposal and in some cases are still used today. These practices are inadequate because of the increasing quantity of waste generated annually, because the waste disposal methods are aesthetically unacceptable, and because they result in extensive surface and ground water contamination.

The objective of this paper is to provide an overview of solid waste generated in the United States. Quantities, composition, and disposal techniques are discussed for the major waste streams — municipal, industrial, mining and milling, agricultural, and energy source generation of solid waste. "The term 'solid waste' means any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities" as defined by The Resource Conservation and Recovery Act (RCRA) of 1976 (PL94-580).

Three steps were required to gather the data. The first was to search the literature for published reports and books on solid waste. This was accomplished by using the computerized literature search capabilities of the Los Alamos Scientific Laboratory (LASL) library system and the Solid Waste Retrieval Information Service conducted by the U. S. Environmental Protection Agency (EPA). The second step involved contacting several governmental agencies (EPA, U. S. Department of Agriculture, U. S. Forest Service, and the U. S. Bureau of Mines) to acquire more recent and unpublished data. The final step was to contact departments of solid waste management in each state and obtain information on their solid waste generation rates and disposal practices.

The first attempt at regulation of solid waste was in 1899 with the Rivers and Harbors Act, which regulated the dumping of debris in navigable waters and adjacent lands. The passing of the Solid Waste Disposal Act of 1965 (PL89-272) initiated the regulation of solid waste disposal. This law provided for creation of the Bureau of Solid Waste Management in the Department of Health, Education, and Welfare. The Act initiated research

and development of national solid waste programs and provided support, both financial and technical, to state and local agencies for solid waste management planning. In 1970, the Resource Recovery Act (PL91-512) amended the Solid Waste Disposal Act and the U. S. EPA was formed, taking on the responsibilities of the Bureau of Solid Waste Management. The amended act shifted the primary objective of the national solid waste management program from disposal to recycling, resource recovery, and energy conversion of wastes and required the EPA to establish guidelines for recovery, collection, separation, and disposal techniques for solid waste.[1]

RCRA replaced the existing laws in 1976. The EPA was given a larger and more responsible part in solid waste management by the Act. RCRA, as amended by the Quiet Communities Act of 1978, will "provide technical and financial assistance for the development of management plans and facilities for the recovery of energy and other resources from discarded materials and for the safe disposal of discarded materials, and to regulate management of hazardous waste."

In 1977 over 5 billion metric tons of solid waste were generated by communities and institutions, industry, agricultural operations, mining processes, and energy production in the United States. Table I breaks down the total by waste source. Agricultural wastes account for more than half of the total waste generated annually, mining and milling 39%, industrial sources (hazardous and nonhazardous) 6.5%, municipal wastes 3%, energy production wastes 1.3%, and radioactive waste <0.1%.

II. MUNICIPAL WASTE

Residential, commerical, and institutional wastes constitute the 132 million metric tons of municipal waste generated in 1977.[2] The EPA calculates that enough municipal waste is generated annually to fill the New Orleans Superdome from floor to ceiling, twice daily, including holidays and weekends. This amount results in per capita generation of 590 kg (1300 lb) per year. Two-thirds of the waste (88 million metric tons) consisted of manufactured products and packaging materials. The composition of post-consumer and commerical solid waste is presented in Table II. Only 7% of the waste was recycled or recovered as an energy source (9.2 million metric tons). As much as 25% could be recycled using source separation. In 1977, 1% was used as an energy source, and 6% was recycled. Of that, over 90% was paper.[2,3] Table III gives the percentage of solid waste used to produce energy in seven countries.

Approximately 4.5 million (dry) metric tons of sewage sludge from 18 000 waste treatment plants and 41.5 million metric tons of unrecycled junked automobiles and construction wastes add to the municipal waste amounts. Greater quantities of sludge are being generated because of more efficient sewage treatment. The EPA expects the total amount of sludge disposed of to double by 1988.[2]

The most common methods of municipal waste disposal presently used are landfilling (not necessarily sanitary), incineration, and composting.[1] Over 90% of disposal is done at landfills; less than one-third meet the minimum requirements to be considered sanitary landfills. Incineration makes up most of the remainder, with composting at <1% of the total.[2] RCRA states that "a facility may be classified as a sanitary landfill and not an open dump only if there is no reasonable probability of adverse effects on health or the environment from disposal of solid waste at such facility." A typical sanitary landfill receives a daily cover of 156 mm (6 in.) of clean soil, which is placed over the compacted refuse in trenches with depths ranging from 1.5 to 6 m (5 to 20 ft). An inventory of numbers and types of all waste sites authorized by RCRA is being done by the EPA. When this inventory is completed, all open dumps will be given 5 yr to upgrade to sanitary landfills or will be required to close.

Cost dictates the method of solid waste management used by most communities. This results in a large number of landfills. Table IV summarizes the results of a study showing costs of various solid waste management methods. There are only a few communities with resource recovery facilities in use or under construction. These are refuse-derived fuel, source separation of resources, small modular incinerators, codisposal of sewage sludge and municipal waste, and waterwall combustion, which produces steam by burning waste.[2]

The EPA stated that in 1976 there were 18 500 municipal solid waste disposal sites covering over

TABLE I

ESTIMATED QUANTITIES OF SOLID WASTE GENERATED IN THE UNITED STATES IN 1977 (wet weight)

Waste Source	Million Metric Tons		Average Per Cent
Municipal	132	(145)[a]	2.5
Sewage Sludge[b]	4.5	(5.0)	0.1
Junked automobiles and construction demolition[b]	41	(45)	0.7
Industrial			
Nonhazardous	292-310	(323-342)	5.6
Hazardous	34-52	(38-57)	0.8
Radioactive[b,c]	0.04	(0.04)	<0.1
Mining and Milling[d]	2086	(2300)	39.0
Agricultural	2265-3014	(2498-3323)	50.4
Utility[e]	70	(77)	1.3
	4925-5710	(5431-6275)	100.0

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[a] Number in parentheses indicates million short tons.
[b] Dry weight.
[c] Accumulated total divided by number of years of waste generation; estimate based on density of 560 kg per m^3, excluding mill tailings.
[d] Tailings in dry weight; includes uranium mill tailings.
[e] Excludes radioactive waste.

Sources: "Solid Waste Facts," SW-694, EPA, May 1978.
"Report to the President by the Interagency Review Group on Nuclear Waste Management," Washington, D. C., 1979.
"Study of Adverse Effects of Solid Wastes From all Mining Activities on the Environment," Draft, PEDCo Environmental, Inc., 1979.
"Hazardous Solid Waste from Agriculture," Raymond C. Loehr, *Environmental Health Perspectives*, Vol. 27, HEW, pp. 261-73, 1978.
"Improving Soils with Organic Waste," USDA, 1978.
"Study of Nonhazardous Wastes from Coal-Fired Electric Utilities, Draft," Radian Corporation, Dec. 1978.

TABLE II

COMPOSITION OF MUNICIPAL REFUSE DISPOSED OF IN 1977 (wet weight)

Material Category	Million Metric Tons	Per Cent
Paper	40.5	33.0
Glass	12.3	10.0
Metals	11.1	9.0
Plastics	4.9	4.0
Rubber and Leather	3.7	3.0
Textiles	1.8	1.5
Wood	4.9	4.0
Miscellaneous Inorganics	1.8	1.5
Food Waste	19.6	16.0
Yard Waste	22.1	18.0
Total	122.7	100.0

Source: "Fourth Report to Congress Resource Recovery and Waste Reduction," Environmental Protection Agency, Report SW-600, 1977.

TABLE III

PERCENTAGE OF SOLID WASTE CONVERTED TO ENERGY (BY COUNTRY) IN 1977

Country	Per Cent
Denmark	60
Switzerland	40
Netherlands	30
Sweden	30
Germany	20
England	10
United States	1

Source: "Solid Waste Facts," SW-694, U. S. Environmental Protection Agency, May 1978.

TABLE IV

SUMMARY OF SOLID WASTE DISPOSAL SYSTEMS ECONOMICS

System Concept	Cost Per Ton*
Incineration only	$7.68
Incineration and residue recovery	7.18
Incineration and steam recovery	7.05
Incineration with steam and residue recovery	6.57
Incineration and electric energy recovery	8.97
Pyrolysis	5.42
Composting (mechanical)	6.28
Materials recovery	4.77
Fuel recovery	2.70
Sanitary landfill (close in)	2.57
Sanitary landfill (remote)	5.94

*Based on municipally-owned, 1000 ton/day plant.

Source: *Solid Waste Management Technology Assessment*, General Electric Company, Van Nostrand Reinhold Company, New York, 1975.

2×10^5 m^2 of land. According to an exclusive survey on disposal practices in the United States by "Waste Age—The Voice of Resource Management," in 1976 there were 15 821 known land disposal sites. In 1977, however, the number of sites decreased by 10.7% to 14 126. Of these sites, only 64 used impermeable liners and 116 had leachate treatment capabilities.[4]

Municipal sewage sludge is disposed of at 23 000 sites. Of the 4.5 million metric tons of sludge generated, 25% is landfilled, 25% used in land spreading (mainly on agricultural lands), 15% is ocean disposed, and 35% is incinerated.[2]

III. INDUSTRIAL WASTE

EPA estimates that 344 million metric tons of industrial wastes were generated in 1977, with an expected growth rate of 3% annually.[2] The composition of these wastes is specific to the industries generating them. Because information on quantities and composition of industrial wastes is limited to the industries that the EPA has studied in depth, a breakdown of industrial waste streams is not complete. Estimated quantities of total waste and hazardous waste generated by industry are presented in Table V. The industries included in the study are thought to be the largest producers of hazardous waste. Table VI shows the quantity of hazardous waste generated by industry. The hazardous constituents in industrial waste are identified in Table VII.

An estimated 10 to 15% or 34 to 52 million metric tons of the total amount of industrial waste produced annually in the United States is hazardous.[2] This does not include radioactive wastes. Ninety per cent of the waste is in liquid or sludge form; by weight 40% of the material is inorganic and 60% is organic. An annual increase of 10 to 15% of hazardous waste is due to the cancelling and banning of toxic substances, i.e., certain pesticides, the increase in chemical production, and consumption rates,[5] and the growing list of wastes now considered toxic. A waste is hazardous if it is reactive, corrosive, ignitable, infectious, radioactive, or toxic. More specific regulations on hazardous wastes are currently being developed. Sixty-five per cent of the hazardous waste is

TABLE V

ESTIMATED QUANTITY OF WASTE GENERATED BY INDUSTRY
(dry weight)

Industry	Total Waste Material 1000 Metric Tons	Total Hazardous Material 1000 Metric Tons
Organic Chemicals	2200 (7000)[a]	2150 (6841)
Smelting and Refining (Cu, Al, Pb, Ti, Sb, W)	8009 (8009)	1270 (1270)
Electroplating and Metal Finishing	115 (1198)	115 (1198)
Inorganic Chemicals	40 000 (68 000)	2000 (3400)
Textile	366 (2221)	47 (1770)
Petroleum Refining	624 (1756)	100 (100)
Rubber Products	550	48
Plastics	2335 (2335)	883 (883)
Electronic Component	37 (60)	26 (35)
Battery	5 (10)	1 (1)
Pulp	9000 (20 300)	0
Explosives	21 (25)	19 (23)
Paint	92	23
Tanning	55 (163)	29 (119)
Smelting and Refining (Iron-Steel)	25 168 (25 168)	3200 (3200)
Smelting and Refining (Iron-Steel including slag)	56 350 (56 350)	3200 (3200)
Feroalloy Foundries	515	350
Ferroalloy Foundries including slag	1925	350
Special Machinery	305 (366)	102 (162)
Pharmaceuticals	274 (1910)	70 (74)

[a]Weights in parentheses are the wet weights; only for available industries.

Source: Office of Solid Waste, Environmental Protection Agency, 1978.

TABLE VI

ESTIMATED QUANTITY OF HAZARDOUS WASTE BY INDUSTRY IN 1977 (wet weight)

Industry	Million Metric Tons
Organic Chemicals	11.7 (12.9)*
Primary Metals	9.0 (9.9)
Electroplating	4.1 (4.5)
Inorganic Chemicals	4.0 (4.4)
Textiles	1.9 (2.1)
Petroleum Refining	1.8 (2.0)
Rubber and Plastics	1.0 (1.1)
Miscellaneous (7 industries)	1.0(1.1)

Numbers in parentheses indicate million short tons.

Source: "Hazardous Waste Fact Sheet," EPA Journal, U.S. EPA, Vol. 5, No. 2, Feb. 1977.

generated in Texas, Ohio, Pennsylvania, Louisiana, Michigan, Indiana, Illinois, Tennessee, West Virginia, and California.[6]

Between 70 and 80% of industrial wastes are disposed of *in situ*. Ninety per cent of the wastes are disposed of by methods not in accordance with Federal regulations. Nonsecure landfills, ponds, and lagoons make up 80%, while 10% is incinerated without proper controls. Available technology options for waste that will meet the standards are secure landfills, controlled incineration, landspreading, chemical fixation, and physical, chemical, and biological treatment of the waste before disposal.[2,6] Hazardous waste treatment and disposal practices are identified in Table VIII. As with municipal waste, cost is the main factor influencing the choice of disposal techniques. Costs of several disposal methods are stated in Table IX.

Over 400 cases of damage from hazardous waste disposal are on file at the EPA. Ground water contamination is the most common type of damage that occurs. It is caused by the leaching of hazardous materials from a disposal site. Other damage incidents have been caused by runoff at disposal sites, which contaminates surface water, explosions and fires due to the combination of reactive chemical wastes or gas production, direct

TABLE VII

BREAKDOWN BY INDUSTRY OF THE HAZARDOUS COMPONENTS IN WASTE

Industry	As	Cd	Cr	Cu	Pb	Hg	Se	Zn	Chlorinated Hydrocarbons	Organics	Cyanides
Chemical Manufacturing			•	•		•			•	•	
Electroplating and Metal Finishing		•	•	•				•			•
Textile			•	•						•	
Petroleum and Coal	•				•				•		
Rubber and Plastics						•		•	•	•	•
Paint and Dye		•	•	•	•	•	•			•	•
Pesticide	•				•	•		•	•	•	•
Electrical and Electronic				•	•	•	•		•		•
Printing and Duplicating	•		•	•	•		•			•	
Explosives	•			•	•	•				•	
Battery		•			•	•		•			
Pharmaceutical	•					•				•	
Pulp and Paper						•				•	
Leather			•							•	

Source: "Report to Congress Disposal of Hazardous Waste," SW-115, U. S. Environmental Protection Agency, 1974.

TABLE VIII

HAZARDOUS WASTE TREATMENT AND DISPOSAL PROCESSES

Treatment	Function*	Inorganics with Heavy Metals	Inorganics	Organics with Heavy Metals	Organics	Radioactive	Biological	Ignitible	Explosive
Physical									
Carbon Sorption	V,S		•	•	•	•			
Dialysis	V,S	•	•	•	•				
Electrodialysis	V,S	•	•	•	•		•		
Evaporation	V,S	•	•			•			
Filtration	V,S	•	•	•	•	•			
Flocculation/ settling	V,S	•	•	•	•	•			
Reverse osmosis	V,S	•	•	•			•		
Ammonia stripping	V,S	•	•	•	•				
Chemical									
Calcination	V	•	•			•			
Ion exchange	V,S,DE	•	•	•	•	•			
Neutralization	DE	•	•	•	•				
Oxidation	DE	•	•	•	•				
Precipitation	V,S	•	•	•	•	•			
Reduction	DE	•	•						
Thermal									
Pyrolysis	V,DE			•	•		•		
Incineration	DE,DI				•	•	•	•	•
Biological									
Activated sludge	DE				•				
Aerated lagoons	DE				•				
Stabilization pond	DE				•				
Trickling filters	DE				•				
Disposal									
Deep-well injection	DI	•	•	•	•		•	•	
Detonation	DI						•		•
Storage	ST	•	•	•	•	•	•	•	•
Land Burial	DI	•	•	•	•	•	•	•	•

*Functions are: V-Volume reduction, S-Separation, DE-Detoxification, DI-Disposal, ST-Storage.

Source: "Report to Congress—Disposal of Hazardous Wastes," SW-115, U.S. Environmental Protection Agency, 1974.

TABLE IX

COSTS OF ADEQUATE DISPOSAL TECHNIQUES FOR HAZARDOUS WASTE

Technique	Cost/Metric Ton
Secure chemical landfill[a]	$30 - 50
Incineration	75 - 265
Landspreading	2 - 25
Chemical fixation	10 - 30
Physical, chemical, biological treatment	varies

[a]Costs vary with volume and type of waste.

Source: Same as Table V.

contact with toxic wastes, air pollution resulting from improper incineration, evaporation, sublimation or wind erosion, and poisoning through the food chain.[6]

An alternative to the disposal of industrial wastes is the transferring of waste to another facility where it would be used as a feedstock.[7] In Europe the transfer of waste has been practiced successfully for several years. Transfers are made by the waste generator to the industry interested in the waste through waste clearinghouses and exchanges. In November 1975, the first U. S. exchange was begun in St. Louis, Missouri. The first listing was of the available wastes and wastes wanted. Several more waste clearinghouses have been, or are now being, established.[8]

IV. RADIOACTIVE WASTE

Defense-related nuclear activities, commercial nuclear reactors, research, medical uses, and uranium mining generate wastes contaminated with radioactive materials.[9] Since the 1940s when defense-related activities were the only producers of radioactive waste, 1.2 million metric tons of waste have accumulated. This amount does not include the uranium mill tailings, more than 127 million metric tons,[9] (that waste is included in the mining and milling waste section of this report). It is important to note that the amount of radioactive waste is total existing waste, not just the amount generated annually, which is approximately 40 000 metric tons. A breakdown by residual type is presented in Table X.

According to the report on Nuclear Waste Management by the Interagency Review Group, radioactive wastes are divided into four categories: high level, transuranic, low level, and uranium mine and milling wastes. These wastes are made up of both natural and man-made radioactive materials and include radioactive species of nearly all chemical elements.[9]

High level waste (HLW) properties are penetrating radiation, high intensity, and long-lived radioactivity.[10] These wastes consist of defense wastes from the Department of Energy (DOE) research and development programs, spent fuel (discarded fuel assemblies from nuclear reactors), and spent fuel reprocessing wastes. Of the 265 440 m^3 of defense-related HLW, 40% is liquid and 60% is either in sludge or salt cake form.[9] These wastes are being stored until acceptable disposal techniques have been approved. Commerical HLW is liquid and is stored in underground tanks. Spent fuel generated at commerical nuclear reactors is also being stored. At present, no spent fuel is being reprocessed in the United States.

Transuranic (TRU), as defined by the DOE, is a waste containing more than 10 nanocuries of a transuranium element per gram of waste. Reprocessing of spent fuel and the fabrication of plutonium produce TRU wastes. Until the early 1970s, defense-related TRU wastes, along with low level wastes, were buried in shallow land burial grounds on DOE lands. Since that time, DOE TRU waste has been stored for future retrieval. As of 1977, 123 kg of TRU waste have been buried at commercial sites. Since 1977, only one of the six commerical radioactive waste disposal areas continued to accept TRU waste for burial.[9]

Any radioactive waste that is not HLW or TRU waste termed low level waste (LLW). These wastes contain no transuranium elements or less than 10 nanocuries of transuranium element activity per gram of material. Approximately 30% of commerical LLW is generated by medical facilities, academic institutions, and industry.[10] LLW is disposed of by shallow land burial. Burial occurs in pits or trenches in the transition zone between soil and subsurface geology.

TABLE X

EXISTING QUANTITIES OF RADIOACTIVE WASTE AS OF JANUARY 1977 (cumulative)

Waste Type	Volume (m^3)	Metric Tons[a]
High level waste		
Commercial	2240	1269
Defense	263 200	149 202
	265 440	150 471
Transuranic waste		
Commercial		0.12
Defense		1.09
		1.21
Spent fuel		2300
Low level waste		
Commercial	442 400	250 786
Defense	1 422 400	806 323
	1 864 800	1 057 109
Subtotal		1 209 881.21
Uranium mill tailings		126 980 000
TOTAL		128 189 881.21

[a] Metric tons estimate based on density of 560 kg per m^3.

Source: "Report to the President by the Interagency Review Group on Nuclear Waste Management," March 1979, Washington, D.C.

V. MINING AND MILLING WASTES

The mining and milling industries produce 2 billion metric tons of waste annually. This quantity increases yearly because of the increasing demand for ore, because the ore mined is a lower grade, and because the ore bodies are at lower depths.[12] As of 1968, an estimated 19 billion metric tons of waste had accumulated from these industries.[2] Another estimate stated that by 1975 27 billion metric tons of waste would exist in the United States. In 1975, over 20 000 active mines, producing 2.9 billion metric tons of crude ore, generated 2.1 billion metric tons of waste, i.e., metallic, nonmetallic, and coal mining (excluding coal mine wastes). By the year 2000, it is estimated that 4 to 6 billion metric tons of wastes will be generated annually.[13]

There are over 65 mining industries generating solid waste (Table XI). Eighty-five per cent of the waste is produced by five industries. The copper industry is the largest generator of waste followed by the iron, phosphate, uranium, and bituminous coal industries. These industries use surface min-

TABLE XI

SOLID WASTE GENERATION BY MINING AND MILLING INDUSTRIES (1000 metric tons)

Commodity	Mine Wastes	Tailings[a]	1975 Total	1977 Estimate (Mining Wastes & Tailings)
Metals				
Copper	626 152	242 036	868 192	930 946
Iron	233 906	140 218	374 124	255 541
Uranium	141 873	7 010	148 883	203 008
Gold	8 383	9 187	17 570	27 212
Bauxite	12 063	1 276	13 339	16 217
Lead	2 222	8 418	10 641	11 006
Zinc	2 523	7 371	9 894	12 566
Silver	335	1 003	1 338	4 546
Mercury	462	54	516	2 356
Others[b]	41 162	NA[c]	41 162	37 720
Total	1 069 085	416 573	1 485 658	1 501 118
Nonmetals				
Phosphate Rock	195 912	124 531	320 443	320 878
Stone	65 948	NA	65 948	67 773
Sand & Gravel	NA	35 781	35 781	40 724
Clays	33 659	NA	33 659	43 877
Potassium Salts	417	14 294	14 711	16 476
Gypsum	12 341	461	12 802	17 650
Sodium Carbonate	3 673	3 673	7 310	11 246
Feldspar	1 796	569	2 365	2 624
Talc, Soapstone, Pyrophyllite	1 604	84	1 689	3 313
Salt	639	876	1 515	4 711
Asbestos	227	1 227	1 454	1 584
Diatomite	770	270	1 040	1 136
Mica	230	414	644	1 599
206				
Perlite	18	177	195	296
Pumice	107	2	109	112
Others[d]	25 246	NA	25 246	23 509
Total	342 588	182 323	524 911	557 502
Mineral Fuels				
Coal (Bituminous & Lignite)[e]	NA	97 141	97 141	105 620
Grand Total	1 411 673	696 037	2 107 619	2 058 620

[a]Tailings in dry weight.
[b]Antimony, beryllium, maganiferous ores, molybdenum, monazite, nickel, platinum, rare-earths, tin, titanium, tungsten, vanadium.
[c]Information not available.
[d]Abrasives, aplite, barite, boron, fluorspar, graphite, greensand marl, iron oxide pigments, kyanite, lithium, magnesite, milstone, oilvine, vermiculite.
[e]The quantity of mine waste for coal mining industry not included; it is larger than all industry mine wastes added together.

Source: "Study of Adverse Effects of Solid Wastes From all Mining Activities on the Environment—Draft," PEDCo Environmental, Inc., 1979.

ing (open pit) to some extent. As the depth at which the ores are mined increases and the ore grade decreases, the quantity of waste increases.[13]

Wastes are generated during the extraction of the ore (mine waste) and during the ore processing (tailings). Seventy-five per cent of the total waste generated is from the metal mining industry, 20% nonmetal mining industry, and 5% coal mining industry (excluding coal mines wastes). Either surface or underground mining techniques are used depending on the type of ore body. Surface mining produced 23 times more mine and tailings waste than did underground mining in 1975.[13]

Mine wastes, overburden, or waste rock made up 68% of the total waste generated in 1975. Overburden consists of varying quantities of topsoil, bedrock, sand, silt, and gravel. Waste rock is mined rock or ore that has no significant value therefore is not processed. The coal industry generates more mine waste than do all other industries. Disposal of mine waste takes place at or near the mine site. Approximately 90% is placed in waste piles, while 10% is used as backfill in excavated mines.[13] Topsoil is often saved and used during reclamation of the land. The future trend in disposal is to increase the amount of overburden and waste rock used as backfill in the mines.

Tailings comprise 32% of the 2.1 billion metric tons of mining and milling wastes. As surface mining generates large quantities of mine wastes, underground mining generates 80% of the tailings. Tailings are finely crushed ore rock (gangue) that undergoes different types of processing. Tailings are composed of various amounts of quartz, feldspar, carbonates, oxides, other minerals, and trace amounts of reagents added during processing. They are typically 50 to 85% water by weight, but can also be processed dry. Over 99% of tailings in a slurry form are disposed of in tailings ponds, with or without liners. The small percentage not disposed of in ponds is used as backfill, discharged into water, or used as construction materials.[13]

Mining and milling of uranium generates large quantities of waste because the uranium-bearing ores are only 0.15 to 0.25% uranium by weight. Therefore the amount of tailings generated is almost equal to the amount of ore mined.[11] The uranium tailings have low concentrations of natural radioactivity and are stored at the mining or milling sites.

VI. AGRICULTURAL WASTE

Limited and varying information is available on agricultural waste quantities. It is estimated that 2.3 to 3.0 billion metric tons of agricultural residues are generated annually in the United States.[14,15] Agricultural wastes are residues from growing, harvesting, and initial processing of fruits, vegetables, crops, meat, poultry, dairy products, and logging and wood manufacturing. Only 8% of the total quantity of wastes is unused and disposed of.[15] These wastes are divided into four categories: animal manures, crop residues, timber wastes, and food processing wastes (see Table XII).

Manure from cattle, horses, sheep, swine, chickens, and turkeys is included in the 1.1 to 1.8 billion metric tons of animal wastes. About 60% of these wastes is generated and used on pasture, crop, and range lands. The other 40% is generated in confined areas, such as dairy farms, livestock feedlots, and poultry houses.[15] A mechanical manure spreader is the most common method used in land spreading of manure as fertilizer.[16] Less than 10% of all manure is actually disposed of as waste in dumps and landfills. A very small quantity of manure is used in livestock feed, used as an energy source, or used in composting.[15]

Field corn, soybeans, and wheat crops are the largest producers of crop residues.[15] These are residues left after harvesting and grazing has taken place in the field. About 75% is turned under the soil and 20% is fed to livestock.[14] Only 3% becomes waste, mostly from cotton crops, and is usually burned.[15]

Timber residues are from logging and wood manufacturing operations. About 80% of logging residues are unmarketable and left in the forest. Some of this is used as fire wood.[15] Eighty-five per cent of wood manufacturing residues are used by other industries, leaving 15% as waste.

Fruit processing is the largest contributor of food processing wastes (see Table XIII). Residues consist of peelings, unusable or unacceptable food, and dairy processing wastes. Eighty per cent is used as feed for livestock, 3% is used in the manufacture of byproducts, and about 17% is disposed of as waste.[15] Land disposal, landfilling, or land spreading are the most common methods of disposal.

TABLE XII

ESTIMATED QUANTITIES OF AGRICULTURAL WASTE TYPES
(million metric tons)

Type	Total Residues	Unused Residues
Manure	1088 - 1814	109 - 184
Crop	1088	33
Timber		
Logging	24 - 36	19 - 29
Manufacturing	63 - 73	9 - 11
Food Processing	1.8 - 2.9	0.3 - 0.4
Total	2265 - 3014	171 - 257

Source: "Hazardous Solid Waste from Agriculture," Raymond C. Loehr, *Environmental Health Perspectives*, Vol. 27, pp. 261-273, 1978. "Improving Soils with Organic Wastes," U.S.D.A., 1976.

VII. UTILITY WASTE

Coal-fired power plants are the largest producers of utility wastes. In 1977 about 65 million metric tons (dry weight) of waste was generated by 399 utility-owned plants.[17] Seventy per cent of all steam turbines are powered by fossil fuel. About 56% of the fossil fuel used was coal, 27% oil, and 17% gas.[18] Nuclear powered steam turbines also produce solid waste and were discussed in the radioactive waste section. Gas- and oil-fired plants produce small quantities of waste. In Table XIV the type of waste generated by fuel used is presented.

TABLE XIV

WASTE CATEGORIES GENERATED BY STEAM POWER PLANTS

	Fuel			
	Coal	Oil	Gas	Nuclear
Maintenance				
Boiler or Generator Tubes	•	•	•	•
Boiler Fireside	•	•	•	
Air Preheater	•	•	•	
Small Equipment	•	•	•	
Stack	•	•	•	
Cooling Tower Basin	•	•	•	•
Bottom Ash	•			
Fly Ash	•	•		
Air Pollution Control Devices	•	•		

Source: "The Impact of RCRA (PL 94-580) on Utility Solid Wastes," Fred C. Hart Associates, Inc., EPRI, August 1978.

TABLE XIII

FOOD PROCESSING WASTES

Item	Million Metric Tons	Per Cent
Fruit	1.8	55
Vegetable	1.1	34
Sugar	0.11	3.5
Seafood	0.09	3
Dried Fruit	0.06	2
Fats & Oils	0.02	0.7
Others*	0.05	1.8

*Miscellaneous food processing wastes, including dairy.

Source: "Improving Soils with Organic Wastes," U.S.D.A., 1978.

The three major types of waste generated at coal-fired utilities are fly ash, bottom ash, and scrubber sludge. The quantity of waste depends on the quality and type of coal burned, scrubber type used, and emission regulations. Ash is produced by the mineral content of the coal, whereas scrubber sludge is from the sulfur content of the coal.[17]

Fly ash, very fine particles drawn along with the flue gas, vary in chemical makeup. Silicon, aluminum, and iron compounds are present in all fly ash, with varying amounts of calcium, magnesium, sodium, and sulfur compounds. Thirty-three per cent less fly ash is produced by western coal than eastern coals. Disposal of fly ash is normally done on or near the generation site. Of the 44.4 million metric tons of fly ash generated, 34% was ponded and 51% landfilled.[17] Other techniques, such as utilization in construction and mine disposal, are used on the remainder of the fly ash.

Ash collected at the bottom of the furnace, either wet or dry, is called bottom ash. Coarse particles with chemical characteristics similar to fly ash are produced. Ponding was the disposal method used most frequently on the 17.2 million metric tons (44%); 29% was disposed of in a landfill. Landfilling and utilization are the disposal techniques favored for the future disposal of fly ash and bottom ash; in 1977, 12.7 million metric tons of ash were successfully recovered and used.[17] Utilization varies; the largest use of ash has been in cement and concrete construction materials.

Scrubber sludge is made up of calcium sulfite coprecipitates, gypsum, and calcium carbonate compounds. Flue gas desulfurization methods scrub out the volatiles (sulfur dioxide) before the gas is released from the stack. Three million metric tons of scrubber sludge produced in slurry form were generated in 1977. Approximately 60% was ponded and 40% landfilled. Three alternate disposal methods are being considered: mine disposal (which seems to be the most feasible), ocean disposal, and land farming. Western coal generates 95% less scrubber sludge than eastern coals because of differences in sulfur content.[17]

Oil burning power plants also produce small quantities of fly ash and scrubber sludge wastes. The ash content of oil normally varies between 0.1 to 0.15% by weight. The chemical makeup of the ash is mostly vanadium, nickel, iron oxides, inorganic salts, organometallic compounds, and carbon. Disposal of the waste is a problem because of the settling and solubility characteristics of the ash. Some recycling of the ash has been done.[18]

VIII. DISCUSSION AND CONCLUSION

The largest quantity of solid waste generated annually in the United States is from agricultural processes. However, because of the nature, composition, and utilization of these residues, in most cases they create little impact on the environment. Approximately 220 million metric tons (8% of total agricultural waste) are actually disposed of as waste, most of which is manure, while over 90% is utilized in some capacity. Use of manure as an energy feedstock is a possible alternative to waste disposal, but is limited by cost. Environmental problems have resulted from improper handling and disposal of these wastes. Biodegradable organics are the major constituent of these wastes; hazardous conditions result only if oxygen resources are not available to assimilate the waste.[14]

The second largest generators of solid waste are mining and milling industries. Because of the mineral content or aggregate properties of these wastes, about 60% have some economic value. There is a need for more research and development into recovery programs for the various minerals in these wastes. To prevent hazards to public health and safety, i.e., wind erosion of tailings piles and waste impoundment failure, alternate disposal and reclamation techniques should be further studied.

About 6% of the total waste is made up of industrial processing wastes, both hazardous and nonhazardous. These wastes have been given little attention in the past; however, since the passing of RCRA and increased public awareness and concern, more attention is being directed at industrial waste disposal methods. Because of cost, storage and disposal techniques have been (and still are) inadequate. Many damage reports demonstrate the need for use of environmentally acceptable disposal methods, including secure landfills, which utilize impermeable liners and leachate collection and treatment systems to eliminate ground water contamination, treatment before disposal, i.e., neutralization, and incineration with emission controls. Continued research and development into waste reduction and recycling of wastes is necessary to eliminate and reuse as much of the waste as possible.

Municipal waste, although only 4% of the total waste generated, has received more attention and concern than the other waste categories. Adequate methods for disposal, i.e., sanitary landfills, are available for municipal waste; however, reduction, materials recovery, and use as an energy source are more desirable waste management methods. Cost has limited the number of major recycling and energy production operations, but it is now becoming more feasible to use these methods because of decreasing availability and increasing cost of land, depletion of our natural resources, and the ever-rising cost of energy.

Solid waste from coal-fired utility plants results primarily from bottom ash and, more recently, residues collected by the air pollution control devices installed on the plants for the control of particulates and sulfur dioxide. These wastes made up 1.3% of the total amount of waste generated. Further research is needed into the utilization of the waste ashes and scrubber sludges. The use of the ash in cement has been shown to be an effective way of utilizing the waste as a resource and avoiding disposal on land.

In comparison with the other quantities of waste generated annually, the amount of radioactive waste that has accumulated since the 1940s is relatively small (0.1% of the annual rate). Because

of concern for potential environmental effects by radioisotopes, research should continue into alternative containment and disposal methods for the various types of radioactive waste.

Because of increasing rates of generation of solid waste, methods of disposal that are adequate today will not be adequate by the year 2000. All generators of solid waste have a responsiblity for disposing of the waste in a manner that will protect the environment. The ultimate solution to the existing problems with solid waste will be a combination of many factors. Some of the important parts to the solution are:

1. Waste reduction.
2. Resource recovery.
3. Recycling.
4. Reuse by chemical change.
5. Design of longer-lasting consumer products.

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